Appendix J
Sample Problem

J-1. Problem Description

A six-year-old wire rope used on a frequently used gate-lifting device located in a warm, humid fresh-water environment is inspected. The inspection reveals that the rope is near failing from corrosion as there are many large corrosion pits and rusty areas. The inspection also indicates fatigue is a problem as many broken wires are present. There is no indication of abrasion.

J-2. Equipment Description/Analysis

a. Drum/sheave arrangement. 10-part as shown in Figure J-1.

b. Sheave pitch diameter. 45 inches.

c. Sheave bearings. Plain.

d. Maximum load (gate weight, friction draw down, etc): 132 tons.

e. Rope: 1-1/2-in. 6x30G flattened strand, right regular lay, improved plow steel (uncoated), IWRC.

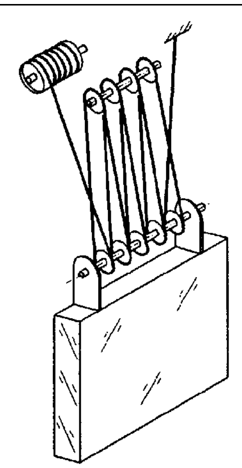

Figure J-1. Drum/sheave arrangement

Per Chapter 4, Figure 4-3, the dynamic rope tension is 0.156 of the load for a lift mechanism with a 10-part sheave arrangement. Therefore, dynamic rope tension would be:

0.156 x 132 tons = 20.6 tons

Per Appendix C Table 8, the nominal strength of the existing rope was 119 tons when new, and per Chapter 4, Figure 4-5, the 30:1 D/d ratio for bending over the sheaves results in a rope efficiency of 0.95. Therefore, the factor of safety for the existing rope when new was:

(119 tons/20.6 tons) x .95 = 5.5 FOS

In short, the factor of safety is adequate for the requirements given in Chapter 4, Paragraph 4-5, and the bending radius is the minimum recommended in Chapter 4, Figure 4-11 (for 6x30 G Flattened Strand rope). It appears the rapid corrosion was caused by the humid environment and fatigue resulted from frequent use of the gate.

J-3. Potential Solutions

a. A first thought may be to replace the existing rope with a one of a similar construction but of stainless steel instead of improved plow steel, since Chapter 2, Paragraph 2-5, states that “The stainless steels are many times more corrosion resistant than the carbon.” However, this paragraph also states that with stainless steels a 10 to 15 percent loss in strength should be expected. Compared to the 5.5 factor of safety for the existing rope when new, a new rope of the same construction, but of stainless steel (with a 15 percent strength reduction) would have a 4.7 factor of safety, which is lower than required according to Chapter 4, Paragraph 4-5. In addition, the inspection revealed many broken wires, which is a sign of fatigue. Merely changing to stainless steel would not reduce fatigue.

b. Given the same load, fatigue could be reduced by changing to lang lay construction. Per Chapter 2, Paragraph 2-2, lang lay rope has better resistance to fatigue while it is equal in strength. It tends to rotate in use, but this is not a problem if both ends are constrained.

c. Also, fatigue could be reduced by changing to a configuration with smaller wires such as 6x37. Note that as previously stated, the bending radius of 30:1 is the minimum recommended for 6x30 G flattened strand rope. The minimum bending radius for 6x37 according to Chapter 4, Figure 4-11, is 26:1. From Chapter 4, Figure 4-12, it would appear this increase from minimum could produce a significant reduction in fatigue. Normally smaller wires would increase corrosion, but in conjunction with a change to stainless steel, this would not likely be a problem.

d. A significant problem would be the loss of strength. A 1-1/2-inch rope of 6x37 IWRC construction and of improved plow steel has a nominal strength of 99 tons according to Appendix C, Table C4. This 17 percent strength reduction would result in a factor of safety of 4.6 for the same rope tension. Combined with a 15 percent strength reduction for changing to stainless steel, the factor of safety would only be 3.9 for the same rope tension.

e. It would appear that changing to a stainless steel rope of 6x37 IWRC construction would solve both the corrosion and fatigue problems except that the factor of safety would be lower than required. Note that the sheaves use plain bearings. As stated in Chapter 4, Paragraph 4-4, the rope tension for sheaves with plain bearings can be much higher than for sheaves with roller bearings. Chapter 4, Figure 4-3, shows that the rope tension for the existing 10-part plain bearing sheave is 0.156 of the load. Therefore, rope tension with a plain bearing sheave is calculated using the following equation:

$$0.156 \text{ x } 132 \text{ tons} = 20.6 \text{ tons} \qquad \text{(J-1)}$$

If the sheave were replaced or modified to use roller bearings, Chapter 4, Figure 4-3, indicates the rope tension would be 0.123 of the load. Tension is calculated using the following:

$$0.123 \text{ x } 132 \text{ tons} = 16.2 \text{ tons} \qquad \text{(J-2)}$$

The factor of safety for a stainless steel rope of 6x37 IWRC lang lay construction combined with a roller bearing sheave would then be as follows:

$$(99 \text{ tons}/16.2 \text{ tons}) \text{ x } .95 = 5.8 \text{ FOS} \qquad \text{(J-3)}$$

The factor of safety of 5.8 is better than required.

f. Further investigation would be required to determine if modifying the sheaves to use roller bearings is the cost effective solution. Also, before proceeding with this solution, it would be wise to contact technical specialists at wire rope companies to see if they agreed that this is a solution to the problem.